

## wagetemp.R

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```
library(tidyverse)

## Warning: package 'tidyverse' was built under R version 4.0.3

## -- Attaching packages ----- tidyverse
1.3.0 --

## v ggplot2 3.3.3      v purrr  0.3.4
## v tibble  3.1.0      v dplyr  1.0.5
## v tidyr   1.1.3      v stringr 1.4.0
## v readr   1.4.0      v forcats 0.5.1

## Warning: package 'ggplot2' was built under R version 4.0.3
## Warning: package 'tibble' was built under R version 4.0.4
## Warning: package 'tidyr' was built under R version 4.0.4
## Warning: package 'readr' was built under R version 4.0.3
## Warning: package 'purrr' was built under R version 4.0.3
## Warning: package 'dplyr' was built under R version 4.0.4
## Warning: package 'stringr' was built under R version 4.0.3
## Warning: package 'forcats' was built under R version 4.0.3

## -- Conflicts -----
tidyverse_conflicts() --
## x dplyr::filter() masks stats::filter()
## x dplyr::lag()    masks stats::lag()

library(broom)

## Warning: package 'broom' was built under R version 4.0.4

library(ISLR)

## Warning: package 'ISLR' was built under R version 4.0.4

library(ggplot2)
attach(Wage)
# Set options, random number generator seed value, & ggplot geom() + th
# eme()
```

```

# arguments
options(max.print=25)
set.seed(76)
update_geom_defaults("point", list(size = 0.5))
update_geom_defaults("path", list(size = 1, colour="red"))
update_geom_defaults("line", list(size = 1, colour="blue"))
theme() + theme_update(axis.title.y=element_blank())

## List of 93
## $ line                                     :List of 6
## ..$ colour                               : chr "black"
## ..$ size                                 : num 0.5
## ..$ linetype                             : num 1
## ..$ lineend                             : chr "butt"
## ..$ arrow                               : logi FALSE
## ..$ inherit.blank: logi TRUE
## ..- attr(*, "class")= chr [1:2] "element_line" "element"
## $ rect                                     :List of 5
## ..$ fill                                 : chr "white"
## ..$ colour                             : chr "black"
## ..$ size                               : num 0.5
## ..$ linetype                           : num 1
## ..$ inherit.blank: logi TRUE
## ..- attr(*, "class")= chr [1:2] "element_rect" "element"
## $ text                                    :List of 11
## ..$ family                             : chr ""
## ..$ face                               : chr "plain"
## ..$ colour                             : chr "black"
## ..$ size                               : num 11
## ..$ hjust                             : num 0.5
## ..$ vjust                             : num 0.5
## ..$ angle                             : num 0
## ..$ lineheight                        : num 0.9
## ..$ margin                            : 'margin' num [1:4] 0points 0points 0points 0points
## ..- attr(*, "unit")= int 8
## ..$ debug                             : logi FALSE
## ..$ inherit.blank: logi TRUE
## ..- attr(*, "class")= chr [1:2] "element_text" "element"
## $ title                                  : NULL
## $ aspect.ratio                          : NULL
## $ axis.title                            : NULL
## $ axis.title.x                          :List of 11
## ..$ family                             : NULL
## ..$ face                               : NULL
## ..$ colour                             : NULL
## ..$ size                               : NULL
## ..$ hjust                             : NULL
## ..$ vjust                             : num 1
## ..$ angle                             : NULL
## ..$ lineheight                        : NULL

```

```

## ..$ margin      : 'margin' num [1:4] 2.75points 0points 0points 0points
## .. ..- attr(*, "unit")= int 8
## ..$ debug       : NULL
## ..$ inherit.blank: logi TRUE
## ..- attr(*, "class")= chr [1:2] "element_text" "element"
## $ axis.title.x.top      :List of 11
## ..$ family         : NULL
## ..$ face           : NULL
## ..$ colour         : NULL
## ..$ size           : NULL
## ..$ hjust          : NULL
## ..$ vjust          : num 0
## ..$ angle          : NULL
## ..$ lineheight     : NULL
## ..$ margin         : 'margin' num [1:4] 0points 0points 2.75points 0points
## .. ..- attr(*, "unit")= int 8
## ..$ debug         : NULL
## ..$ inherit.blank: logi TRUE
## ..- attr(*, "class")= chr [1:2] "element_text" "element"
## $ axis.title.x.bottom   : NULL
## $ axis.title.y          :List of 11
## ..$ family         : NULL
## ..$ face           : NULL
## ..$ colour         : NULL
## ..$ size           : NULL
## ..$ hjust          : NULL
## ..$ vjust          : num 1
## ..$ angle          : num 90
## ..$ lineheight     : NULL
## ..$ margin         : 'margin' num [1:4] 0points 2.75points 0points 0points
## .. ..- attr(*, "unit")= int 8
## ..$ debug         : NULL
## ..$ inherit.blank: logi TRUE
## ..- attr(*, "class")= chr [1:2] "element_text" "element"
## $ axis.title.y.left     : NULL
## $ axis.title.y.right    :List of 11
## ..$ family         : NULL
## ..$ face           : NULL
## ..$ colour         : NULL
## ..$ size           : NULL
## ..$ hjust          : NULL
## ..$ vjust          : num 0
## ..$ angle          : num -90
## ..$ lineheight     : NULL
## ..$ margin         : 'margin' num [1:4] 0points 0points 0points 2.75points
## .. ..- attr(*, "unit")= int 8
## ..$ debug         : NULL
## ..$ inherit.blank: logi TRUE
## ..- attr(*, "class")= chr [1:2] "element_text" "element"
## $ axis.text            :List of 11

```

```

## ..$ family      : NULL
## ..$ face        : NULL
## ..$ colour      : chr "grey30"
## ..$ size        : 'rel' num 0.8
## ..$ hjust       : NULL
## ..$ vjust       : NULL
## ..$ angle       : NULL
## ..$ lineheight  : NULL
## ..$ margin      : NULL
## ..$ debug       : NULL
## ..$ inherit.blank: logi TRUE
## ..- attr(*, "class")= chr [1:2] "element_text" "element"
## $ axis.text.x      :List of 11
## ..$ family      : NULL
## ..$ face        : NULL
## ..$ colour      : NULL
## ..$ size        : NULL
## ..$ hjust       : NULL
## ..$ vjust       : num 1
## ..$ angle       : NULL
## ..$ lineheight  : NULL
## ..$ margin      : 'margin' num [1:4] 2.2points 0points 0points 0points
## ..- attr(*, "unit")= int 8
## ..$ debug       : NULL
## ..$ inherit.blank: logi TRUE
## ..- attr(*, "class")= chr [1:2] "element_text" "element"
## $ axis.text.x.top  :List of 11
## ..$ family      : NULL
## ..$ face        : NULL
## ..$ colour      : NULL
## ..$ size        : NULL
## ..$ hjust       : NULL
## ..$ vjust       : num 0
## ..$ angle       : NULL
## ..$ lineheight  : NULL
## ..$ margin      : 'margin' num [1:4] 0points 0points 2.2points 0points
## ..- attr(*, "unit")= int 8
## ..$ debug       : NULL
## ..$ inherit.blank: logi TRUE
## ..- attr(*, "class")= chr [1:2] "element_text" "element"
## $ axis.text.x.bottom : NULL
## $ axis.text.y      :List of 11
## ..$ family      : NULL
## ..$ face        : NULL
## ..$ colour      : NULL
## ..$ size        : NULL
## ..$ hjust       : num 1
## ..$ vjust       : NULL
## ..$ angle       : NULL
## ..$ lineheight  : NULL

```

```

## ..$ margin      : 'margin' num [1:4] 0points 2.2points 0points 0points
## .. ..- attr(*, "unit")= int 8
## ..$ debug       : NULL
## ..$ inherit.blank: logi TRUE
## ..- attr(*, "class")= chr [1:2] "element_text" "element"
## $ axis.text.y.left      : NULL
## $ axis.text.y.right     :List of 11
## ..$ family          : NULL
## ..$ face             : NULL
## ..$ colour           : NULL
## ..$ size              : NULL
## ..$ hjust             : num 0
## ..$ vjust             : NULL
## ..$ angle             : NULL
## ..$ lineheight        : NULL
## ..$ margin           : 'margin' num [1:4] 0points 0points 0points 2.2points
## .. ..- attr(*, "unit")= int 8
## ..$ debug           : NULL
## ..$ inherit.blank: logi TRUE
## ..- attr(*, "class")= chr [1:2] "element_text" "element"
## $ axis.ticks           :List of 6
## ..$ colour           : chr "grey20"
## ..$ size              : NULL
## ..$ linetype          : NULL
## ..$ lineend           : NULL
## ..$ arrow             : logi FALSE
## ..$ inherit.blank: logi TRUE
## ..- attr(*, "class")= chr [1:2] "element_line" "element"
## $ axis.ticks.x          : NULL
## $ axis.ticks.x.top      : NULL
## $ axis.ticks.x.bottom   : NULL
## $ axis.ticks.y          : NULL
## $ axis.ticks.y.left     : NULL
## $ axis.ticks.y.right    : NULL
## $ axis.ticks.length     : 'simpleUnit' num 2.75points
## ..- attr(*, "unit")= int 8
## $ axis.ticks.length.x   : NULL
## $ axis.ticks.length.x.top : NULL
## $ axis.ticks.length.x.bottom: NULL
## $ axis.ticks.length.y   : NULL
## $ axis.ticks.length.y.left : NULL
## $ axis.ticks.length.y.right : NULL
## $ axis.line             : list()
## ..- attr(*, "class")= chr [1:2] "element_blank" "element"
## $ axis.line.x           : NULL
## $ axis.line.x.top       : NULL
## $ axis.line.x.bottom    : NULL
## $ axis.line.y           : NULL
## $ axis.line.y.left      : NULL
## $ axis.line.y.right     : NULL

```

```

## $ legend.background      :List of 5
## ..$ fill                : NULL
## ..$ colour              : logi NA
## ..$ size                : NULL
## ..$ linetype            : NULL
## ..$ inherit.blank: logi TRUE
## ..- attr(*, "class")= chr [1:2] "element_rect" "element"
## $ legend.margin          : 'margin' num [1:4] 5.5points 5.5points
5.5points 5.5points
## ..- attr(*, "unit")= int 8
## $ legend.spacing        : 'simpleUnit' num 11points
## ..- attr(*, "unit")= int 8
## $ legend.spacing.x      : NULL
## $ legend.spacing.y      : NULL
## $ legend.key             :List of 5
## ..$ fill                : chr "grey95"
## ..$ colour              : logi NA
## ..$ size                : NULL
## ..$ linetype            : NULL
## ..$ inherit.blank: logi TRUE
## ..- attr(*, "class")= chr [1:2] "element_rect" "element"
## $ legend.key.size        : 'simpleUnit' num 1.2lines
## ..- attr(*, "unit")= int 3
## $ legend.key.height      : NULL
## $ legend.key.width       : NULL
## $ legend.text            :List of 11
## ..$ family              : NULL
## ..$ face                : NULL
## ..$ colour              : NULL
## ..$ size                : 'rel' num 0.8
## ..$ hjust               : NULL
## ..$ vjust               : NULL
## ..$ angle               : NULL
## ..$ lineheight          : NULL
## ..$ margin              : NULL
## ..$ debug               : NULL
## ..$ inherit.blank: logi TRUE
## ..- attr(*, "class")= chr [1:2] "element_text" "element"
## $ legend.text.align      : NULL
## $ legend.title           :List of 11
## ..$ family              : NULL
## ..$ face                : NULL
## ..$ colour              : NULL
## ..$ size                : NULL
## ..$ hjust               : num 0
## ..$ vjust               : NULL
## ..$ angle               : NULL
## ..$ lineheight          : NULL
## ..$ margin              : NULL
## ..$ debug               : NULL

```

```

## ..$ inherit.blank: logi TRUE
## ..- attr(*, "class")= chr [1:2] "element_text" "element"
## $ legend.title.align : NULL
## $ legend.position : chr "right"
## $ legend.direction : NULL
## $ legend.justification : chr "center"
## $ legend.box : NULL
## $ legend.box.just : NULL
## $ legend.box.margin : 'margin' num [1:4] 0cm 0cm 0cm 0cm
## ..- attr(*, "unit")= int 1
## $ legend.box.background : list()
## ..- attr(*, "class")= chr [1:2] "element_blank" "element"
## $ legend.box.spacing : 'simpleUnit' num 11points
## ..- attr(*, "unit")= int 8
## $ panel.background :List of 5
## ..$ fill : chr "grey92"
## ..$ colour : logi NA
## ..$ size : NULL
## ..$ linetype : NULL
## ..$ inherit.blank: logi TRUE
## ..- attr(*, "class")= chr [1:2] "element_rect" "element"
## $ panel.border : list()
## ..- attr(*, "class")= chr [1:2] "element_blank" "element"
## $ panel.spacing : 'simpleUnit' num 5.5points
## ..- attr(*, "unit")= int 8
## $ panel.spacing.x : NULL
## $ panel.spacing.y : NULL
## $ panel.grid :List of 6
## ..$ colour : chr "white"
## ..$ size : NULL
## ..$ linetype : NULL
## ..$ lineend : NULL
## ..$ arrow : logi FALSE
## ..$ inherit.blank: logi TRUE
## ..- attr(*, "class")= chr [1:2] "element_line" "element"
## $ panel.grid.major : NULL
## $ panel.grid.minor :List of 6
## ..$ colour : NULL
## ..$ size : 'rel' num 0.5
## ..$ linetype : NULL
## ..$ lineend : NULL
## ..$ arrow : logi FALSE
## ..$ inherit.blank: logi TRUE
## ..- attr(*, "class")= chr [1:2] "element_line" "element"
## $ panel.grid.major.x : NULL
## $ panel.grid.major.y : NULL
## $ panel.grid.minor.x : NULL
## $ panel.grid.minor.y : NULL
## $ panel.ontop : logi FALSE
## $ plot.background :List of 5

```

```

## ..$ fill          : NULL
## ..$ colour        : chr "white"
## ..$ size          : NULL
## ..$ linetype       : NULL
## ..$ inherit.blank: logi TRUE
## ..- attr(*, "class")= chr [1:2] "element_rect" "element"
## $ plot.title      :List of 11
## ..$ family        : NULL
## ..$ face           : NULL
## ..$ colour        : NULL
## ..$ size          : 'rel' num 1.2
## ..$ hjust         : num 0
## ..$ vjust         : num 1
## ..$ angle         : NULL
## ..$ lineheight    : NULL
## ..$ margin        : 'margin' num [1:4] 0points 0points 5.5points 0points
## ..- attr(*, "unit")= int 8
## ..$ debug         : NULL
## ..$ inherit.blank: logi TRUE
## ..- attr(*, "class")= chr [1:2] "element_text" "element"
## $ plot.title.position : chr "panel"
## $ plot.subtitle     :List of 11
## ..$ family        : NULL
## ..$ face           : NULL
## ..$ colour        : NULL
## ..$ size          : NULL
## ..$ hjust         : num 0
## ..$ vjust         : num 1
## ..$ angle         : NULL
## ..$ lineheight    : NULL
## ..$ margin        : 'margin' num [1:4] 0points 0points 5.5points 0points
## ..- attr(*, "unit")= int 8
## ..$ debug         : NULL
## ..$ inherit.blank: logi TRUE
## ..- attr(*, "class")= chr [1:2] "element_text" "element"
## $ plot.caption     :List of 11
## ..$ family        : NULL
## ..$ face           : NULL
## ..$ colour        : NULL
## ..$ size          : 'rel' num 0.8
## ..$ hjust         : num 1
## ..$ vjust         : num 1
## ..$ angle         : NULL
## ..$ lineheight    : NULL
## ..$ margin        : 'margin' num [1:4] 5.5points 0points 0points 0points
## ..- attr(*, "unit")= int 8
## ..$ debug         : NULL
## ..$ inherit.blank: logi TRUE
## ..- attr(*, "class")= chr [1:2] "element_text" "element"
## $ plot.caption.position : chr "panel"

```



```

## $ plot.tag :List of 11
## ..$ family : NULL
## ..$ face : NULL
## ..$ colour : NULL
## ..$ size : 'rel' num 1.2
## ..$ hjust : num 0.5
## ..$ vjust : num 0.5
## ..$ angle : NULL
## ..$ lineheight : NULL
## ..$ margin : NULL
## ..$ debug : NULL
## ..$ inherit.blank: logi TRUE
## ..- attr(*, "class")= chr [1:2] "element_text" "element"
## $ plot.tag.position : chr "topleft"
## $ plot.margin : 'margin' num [1:4] 5.5points 5.5points
5.5points 5.5points
## ..- attr(*, "unit")= int 8
## $ strip.background :List of 5
## ..$ fill : chr "grey85"
## ..$ colour : logi NA
## ..$ size : NULL
## ..$ linetype : NULL
## ..$ inherit.blank: logi TRUE
## ..- attr(*, "class")= chr [1:2] "element_rect" "element"
## $ strip.background.x : NULL
## $ strip.background.y : NULL
## $ strip.placement : chr "inside"
## $ strip.text :List of 11
## ..$ family : NULL
## ..$ face : NULL
## ..$ colour : chr "grey10"
## ..$ size : 'rel' num 0.8
## ..$ hjust : NULL
## ..$ vjust : NULL
## ..$ angle : NULL
## ..$ lineheight : NULL
## ..$ margin : 'margin' num [1:4] 4.4points 4.4points 4.4points
4.4points
## ..- attr(*, "unit")= int 8
## ..$ debug : NULL
## ..$ inherit.blank: logi TRUE
## ..- attr(*, "class")= chr [1:2] "element_text" "element"
## $ strip.text.x : NULL
## $ strip.text.y :List of 11
## ..$ family : NULL
## ..$ face : NULL
## ..$ colour : NULL
## ..$ size : NULL
## ..$ hjust : NULL
## ..$ vjust : NULL

```

```

## ..$ angle      : num -90
## ..$ lineheight  : NULL
## ..$ margin      : NULL
## ..$ debug       : NULL
## ..$ inherit.blank: logi TRUE
## ..- attr(*, "class")= chr [1:2] "element_text" "element"
## $ strip.switch.pad.grid : 'simpleUnit' num 2.75points
## ..- attr(*, "unit")= int 8
## $ strip.switch.pad.wrap : 'simpleUnit' num 2.75points
## ..- attr(*, "unit")= int 8
## $ strip.text.y.left     :List of 11
## ..$ family        : NULL
## ..$ face          : NULL
## ..$ colour        : NULL
## ..$ size          : NULL
## ..$ hjust         : NULL
## ..$ vjust         : NULL
## ..$ angle         : num 90
## ..$ lineheight    : NULL
## ..$ margin        : NULL
## ..$ debug         : NULL
## ..$ inherit.blank: logi TRUE
## ..- attr(*, "class")= chr [1:2] "element_text" "element"
## - attr(*, "class")= chr [1:2] "theme" "gg"
## - attr(*, "complete")= logi TRUE
## - attr(*, "validate")= logi TRUE

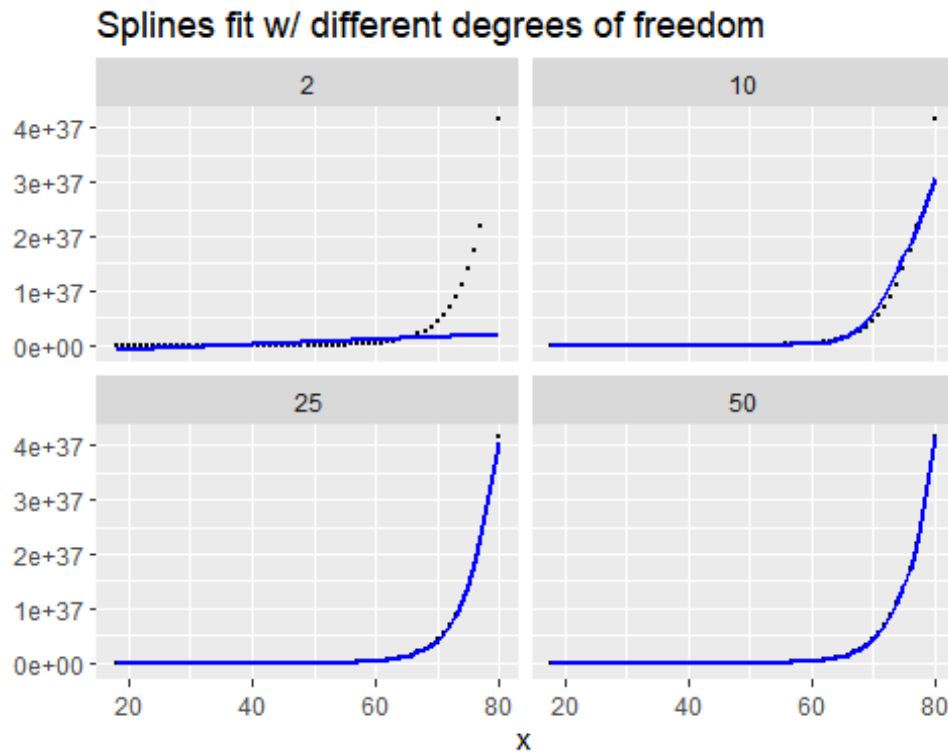
df_values <- c(2, 10, 25, 50)
f <- function(x){
  f_x <- 0.2*x^11*(10*(1-x))^6+10*(10*x)^3*(1-x)^10
  return(f_x)
}
eps = rnorm(3000, 0, sd = 2)
values <- data_frame(
  x=age,
  f_x = f(x),
  epsilon = eps,
  y = f_x + epsilon
)

## Warning: `data_frame()` was deprecated in tibble 1.1.0.
## Please use `tibble()` instead.

overall <- NULL
for(df in df_values){
  overall <- smooth.spline(values$x, values$y, df=df) %>%
    augment() %>%
    mutate(df=df) %>%
    bind_rows(overall)
}

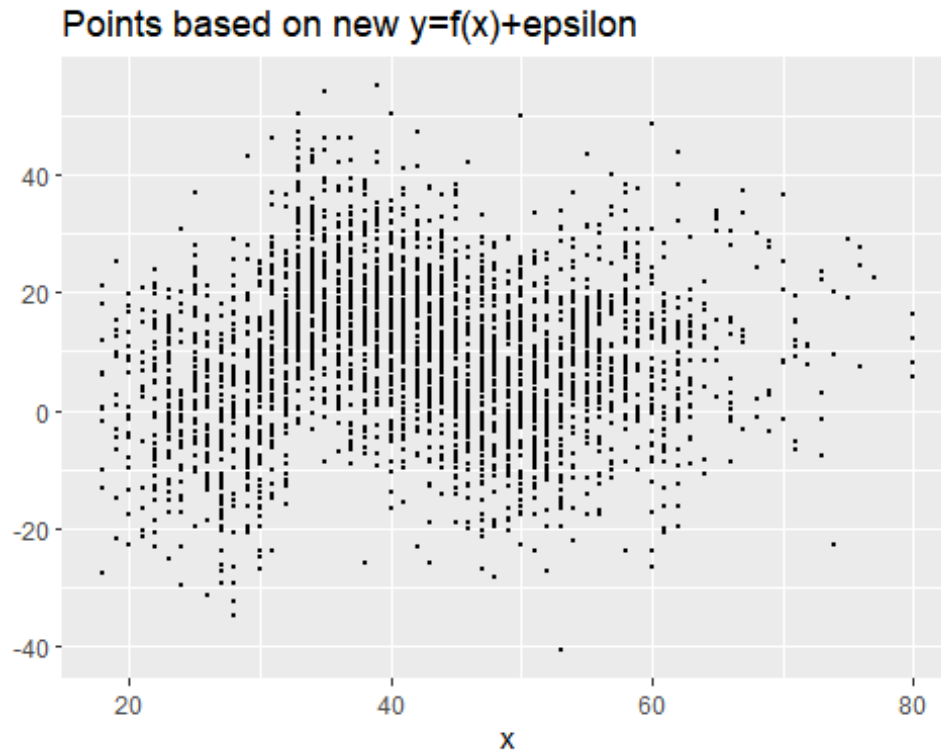
```

```
multiple_df <- overall %>%
  ggplot(aes(x=x)) +
  geom_point(aes(y=y)) +
  geom_line(aes(y=.fitted)) +
  facet_wrap(~df, nrow=2) +
  labs(title="Splines fit w/ different degrees of freedom")
multiple_df
```



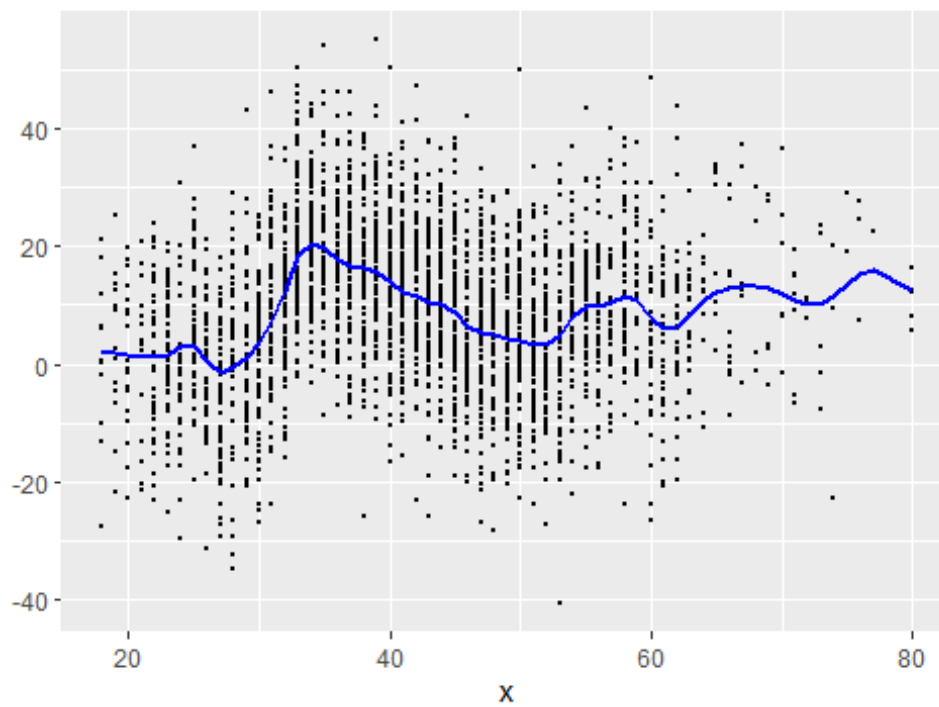
```
f2 <- function(x){
  ifelse(0 < x & x < 5*pi, -6*sin(x),
    ifelse(5*pi < x & x < 25, 0,
      ifelse(25 < x & x < 32, 0.02*(exp(x-25)-1),
        ifelse(32 < x & x < 54, -x+32+0.02*(exp(7)-1), 10)
      )
    )
  )
}
values <- data_frame(
  x = age,
  f_x = f2(x),
  epsilon = rnorm(3000, 0, sd = 12),
  y = f_x + epsilon
)
# Exercise, fitted, and truth plot
exercise <- values %>%
  ggplot(aes(x=x)) +
  geom_point(aes(y=y)) +
```

```
labs(title="Points based on new  $y=f(x)+\epsilon$ ")
exercise
```



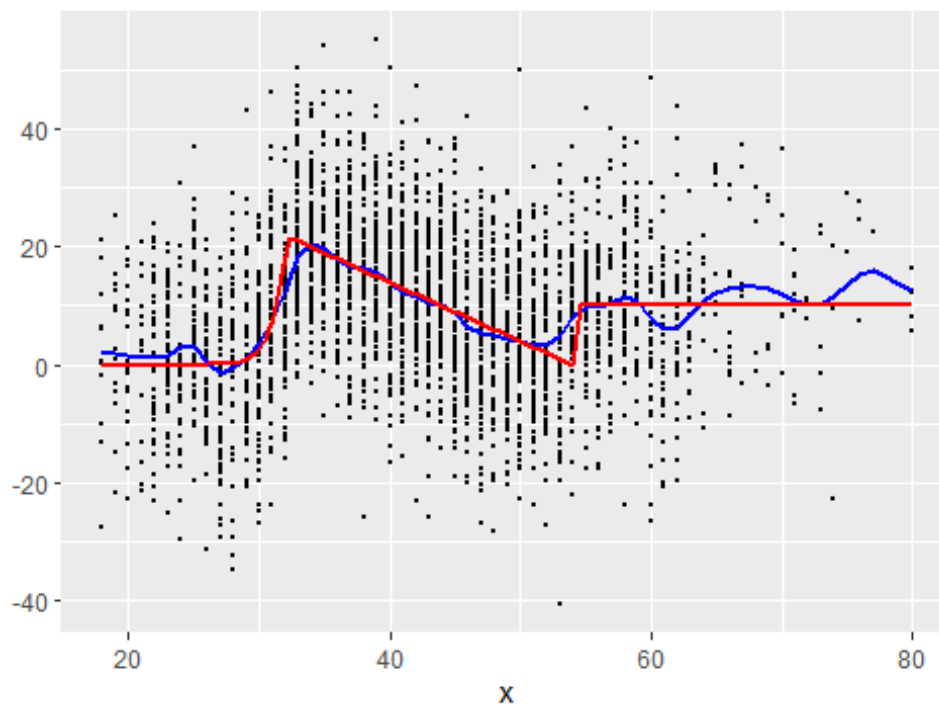
```
fitted <- smooth.spline(values$x, values$y, df=25) %>%
  augment() %>%
  mutate(df=10) %>%
  ggplot(aes(x=x)) + geom_point(aes(y=y)) + geom_line(aes(y=.fitted)) +
  labs(title = "Spline curve (in blue) fit with degrees of freedom = 25 ")
fitted
```

Spline curve (in blue) fit with degrees of freedom = 25



```
truth <- fitted + stat_function(fun = f2) + labs(title = "True function f(x)  
in red")  
truth
```

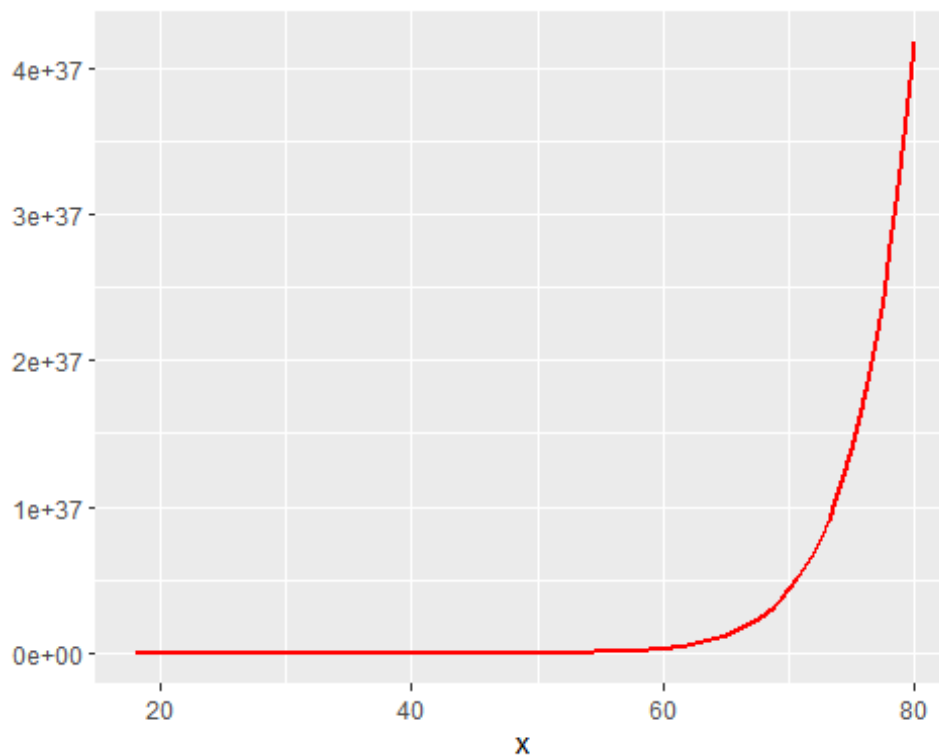
True function f(x) in red



```

library(tidyverse)
library(broom)
# Here is a wacky function f(x)
f <- function(x){
  f_x <- 0.2*x^11*(10*(1-x))^6+10*(10*x)^3*(1-x)^10
  return(f_x)
}
values <- data_frame(
  x = age,
  f_x = f(x)
)
values %>%
  ggplot(aes(x=x)) +
  stat_function(fun = f)

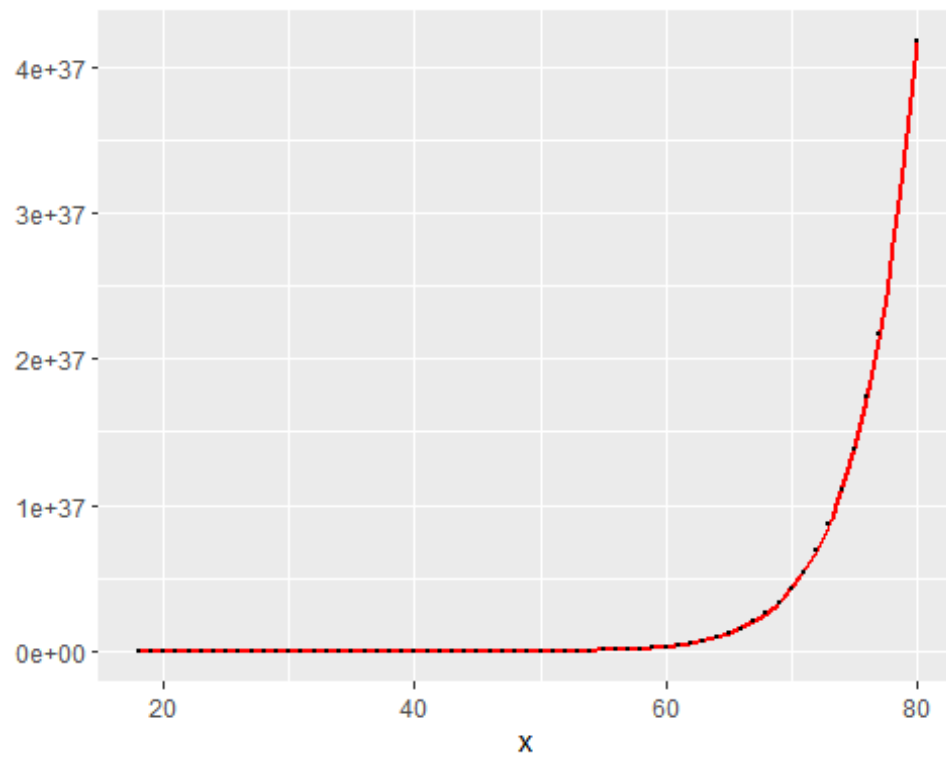
```



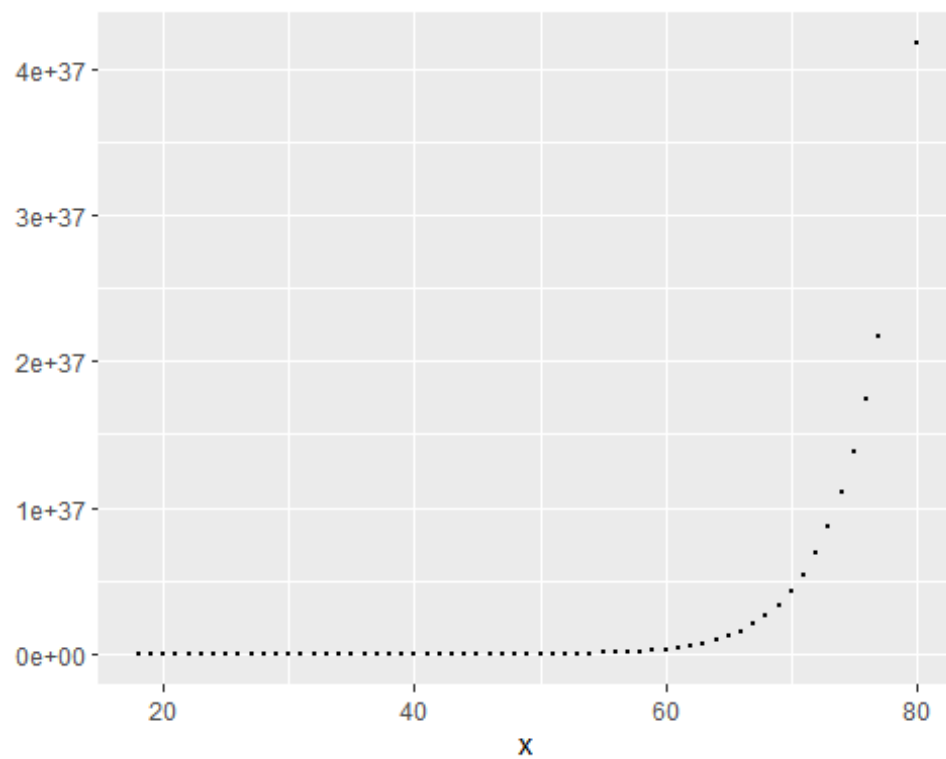
```

values <- values %>%
  mutate( epsilon = rnorm(3000, 0, sd = 2), y = f_x + epsilon )
values %>% ggplot(aes(x=x)) + stat_function(fun = f) + geom_point(aes(y=y))

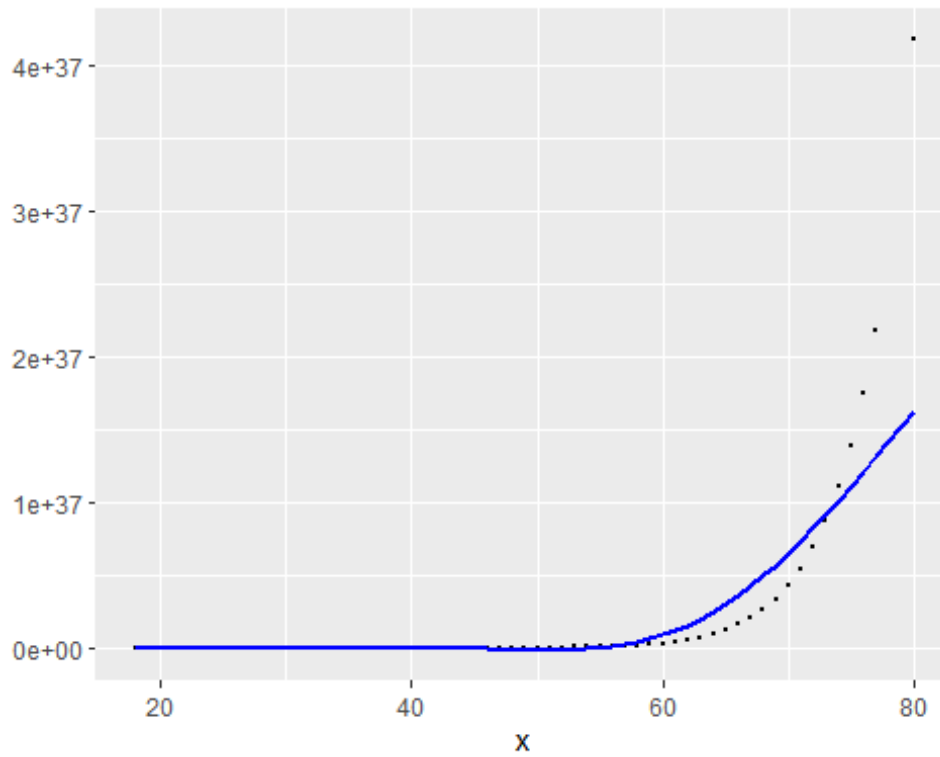
```



```
values %>%  
  ggplot(aes(x=x)) + geom_point(aes(y=y))
```



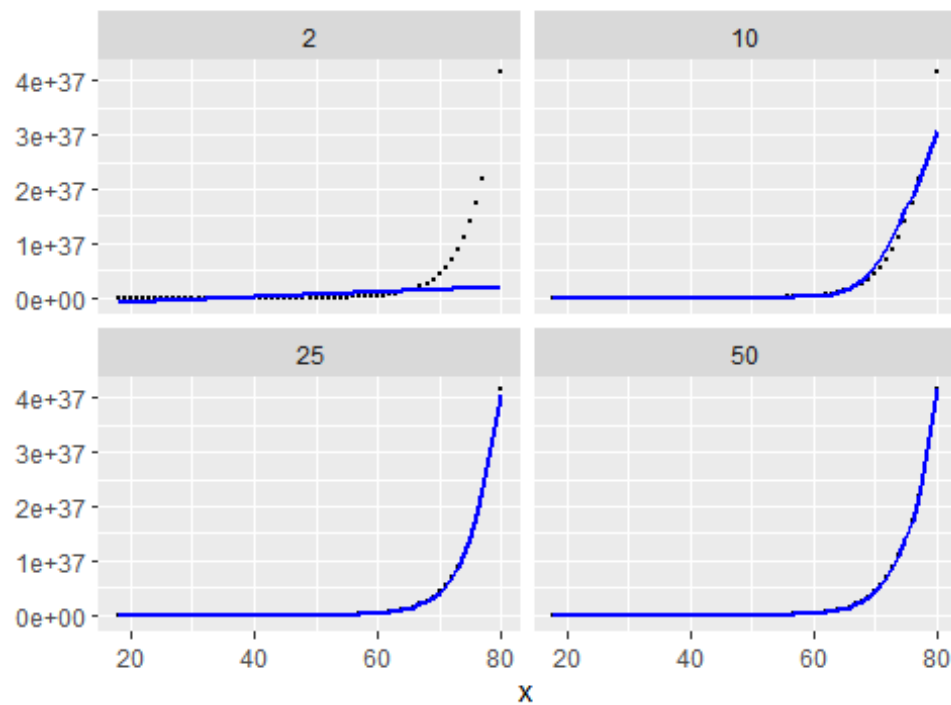
```
smooth.spline(values$x, values$y, df=5) %>%  
  broom::augment() %>%  
  ggplot(aes(x=x)) +  
  geom_point(aes(y=y)) +  
  geom_line(aes(y=.fitted))
```



multiple\_df

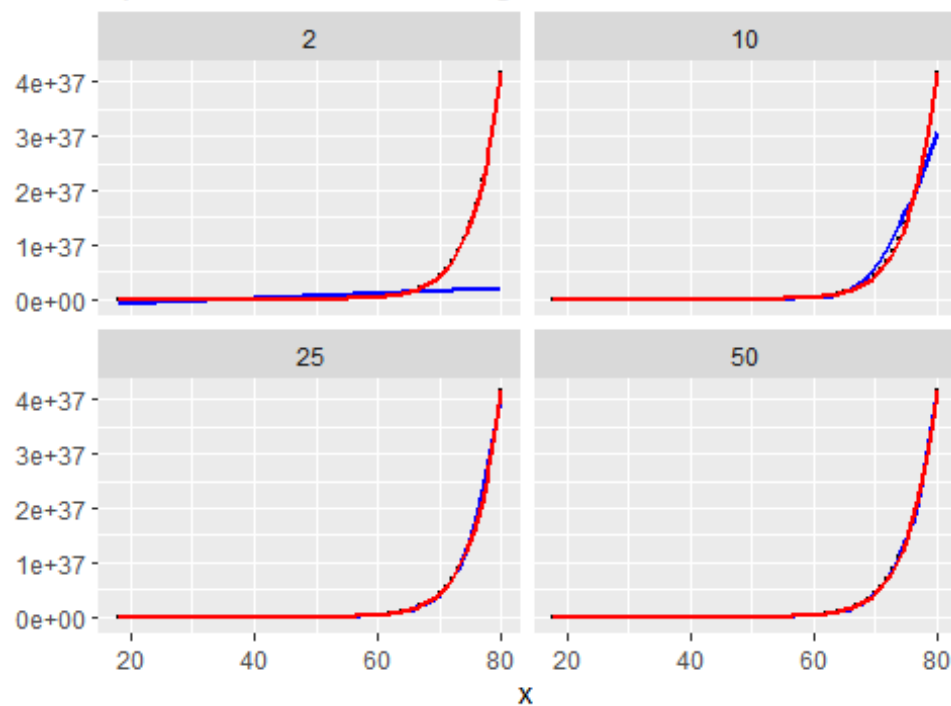


### Splines fit w/ different degrees of freedom



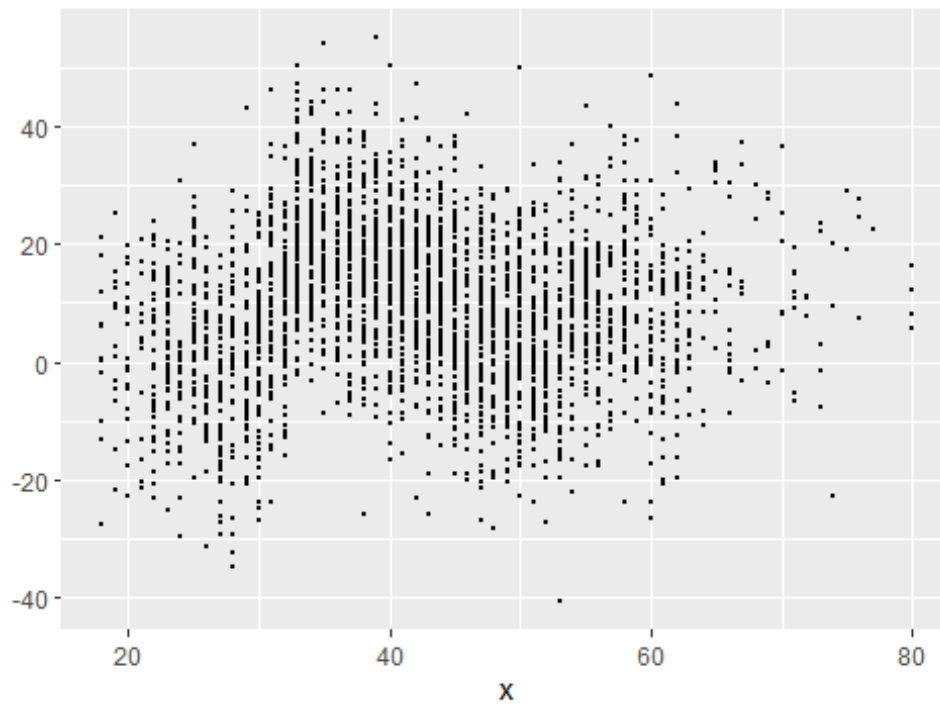
```
multiple_df + stat_function(fun = f)
```

### Splines fit w/ different degrees of freedom



exercise

Points based on new  $y=f(x)+\epsilon$



fitted

Spline curve (in blue) fit with degrees of freedom = 25

